FINAL PROJECT

PRELIMINARY DESIGN OF TERTIARY BUTYL ALCOHOL PLANT FROM ISOBUTYLENE AND WATER CAPACITY OF 80,000 TONS/YEAR

Submitted In Partial Fulfillment of the Requirement for the Degree of Bachelor in Chemical Engineering

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Desi Ratnasari

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Abstrak

Pabrik Tertiary Butyl Alcohol (TBA) memiliki kapasitas 80.000 ton per tahun. Pabrik direncanakan untuk beroperasi selama 330 hari pertahun. Proses pembuatan TBA dilakukan dalam reaktor gelembung fase cair-gas, non-adiabatis dan isotermal. Proses berlangsung pada suhu 70°C dan tekanan 1.4 atm dalam reaksi irreversible dan eksotermis. Pabrik ini dikategorikan pabrik beresiko rendah. Setiap tahun, kebutuhan bahan baku isobutilen adalah 58.192,4872 ton dan air sebanyak 21.880,5938 ton.

Unit pendukung proses (Utilitas) meliputi air pendingin, air sanitasi, air umpan boiler, air proses, steam, listrik, bahan bakar, dan udara tekan. Kebutuhan air total sebanyak 88.334,4799 kg/jam diambil dari Sungai Cimanuk. Kebutuhan steam sebanyak 9.388,1468 kg/jam dan didapatkan dari boiler. Bahan bakar untuk boiler digunakan minyak sebnyak 1.4710 m^3/jam. Kebutuhan udara tekan sekitar 50m^3/jam. Kebutuhan listrik dipenuhi oleh Perusahaan Listrik Negara (PLN) sebanyak 321.62 kW dan generator yang digunakan sebagai cadangan tenaga sebanyak 550 kW dengan menggunakan bahan baku solar sekitar 1.76 m^3/jam. Pabrik didirikan di area industri Indramayu, Jawa Barat. Total area tanah adalah 27,030 m^2. Bahan baku isobutilene didapatkan dari UP VI Balongan, Indramayu, Jawa Barat. Jumlah karyawan sebanyak 125 orang.

Pabrik TBA membutuhkan Rp 480.322.499.166,48 sebagai modal tetap dan Rp 145.074.950.600,34 sebagai modal kerja. Berdasarkan analisis ekonomi, pabrik ini akan mendapatkan keuntungan sebelum pajak sebesar Rp 271.474.519.769,99. Pabrik akan mendapatkan keuntungan setelah pajak 30% sebesar Rp 190,032,163,838.99 per tahun. Jumlah persen dari *Return of Investment* (ROI) sebelum pajak dan sesudah pajak adalah 56.52% dan 39.56% berturut-turut. *Pay Out Time* (POT) sebelum pajak dan sesudah pajak sekitar 1.5 tahun dan 2 tahun. *Break Even Point* (BEP) adalah 42.92% dan *Shut Down Point* adalah 28.46%. *Internal Rate of Return* (IRR) adalah 33%. Berdasarkan dari kelayakn ekonomi, disimpulkan bahwa pabrik TBA layak untuk dibangun.

Kata kunci: Tertiari Butil Alkohol, isobutilen, reaktor gelembung

Abstract

The Tertiary Butyl Alcohol (TBA) plant has a capacity of 80,000 tons per year. The plant is planned to operate for 330 days per year. TBA making process is carried out in a bubble reactor liquid-gas phase, non-adiabatic and isothermal. The

process takes place at a temperature of 70°C and a pressure of 1.4 atm in irreversible and exothermic reaction. This plant is classified low risk plant. Each year, the need for raw materials isobutylene is 58,192.4872 tons and water is 21,880.5938 tons.

Process supporting units (Utilities) consist of cooling water, sanitary water, boiler feed water, process water, steam, electricity, fuel, and compressed air. Total water needed is about 88,384.4799 kg/hour supplied from Cimanuk River. Steam supply is about 9,388.1468 kg/hour then obtained from the boiler. The fuel for boiler is used fuel oil as much as 1.4710 m^3/hour. Compressed air needs is about 50 m^3/hr. Electricity is supplied by State Electricity Company (PLN) as much as 321.62 kW and generator for backup power is about 550 kW by using diesel fuel of 1.76 m^3/hr. The plant was established in the industrial area of Indramayu, West Java. Total land area is 27,030 m^2. Isobutylene raw material is obtained from UP VI Balongan, Indramayu, West Java. The number of employees are 125 people.

TBA plant needs 480,322,499,166.48 IDR of fixed capital and 145,074,950,600.34 IDR of working capital. Based on the economic analysis, the plant will get 271,474,519,769.99 IDR of profit before tax. The plant will get 190,032,163,838.99 IDR of profit after 30% of tax per year. Number of percent Return of Investment (ROI) before tax and after tax is 56.52% and 39.56% respectively. Pay Out Time (POT) before tax and after tax is about 1.5 years and 2 years. Break Even Point (BEP) is 42.92% and shut down point is 28.46%. Internal Rate of Return (IRR) is 33%. Based on the economic feasibility, it is concluded that the TBA plant is feasible to be built.

Keyword: tertiary butyl alcohol, isobutylene, bubble reactor

1. INTRODUCTION

a. Background

As a developing country, Indonesia developed projects in many fields. One of them is a project to build the chemical industry. Currently, Indonesia rely on other countries to meet the raw materials of chemical industry, such as Tertiary Butyl Alcohol (TBA).

The development of industry in Indonesia leads to the increase of Tertiary Butyl's needs. There are many Indonesian people consume TBA, but there is no plant that produces TBA, so that Indonesia still import TBA from other countries. Therefore, it is appropriate if there are companies that build TBA factories in Indonesia. The purpose is to meet the domestic needs, while also abroad.

TBA is used as a solvent, for example in the production of Tertiary Butyl Peroxide. TBA can also be used as a base of glycol ether (1-tertiary butoxy-2-propanol), Isobutylene, methyl-tertiary, butyl ether and tertiary butyl phenol. It can also be used as a mixture of oxinol 50 (the mixed gas that consist of methanol and TBA with 1:1 ratio, additives in gasoline, and anti-pollutant of antiknock gasoline. (Mc. Ketta, 1992)

b. Design Capacity

Determining the capacity to produce TBA is based on the needs of TBA for the industry in Indonesia. As shown in the following table.

Table 1 Data Import of TBA in Indonesia

No.	Year	Capacity (Ton)
1	2006	12,641
2	2007	9,983
3	2008	12,870
4	2009	17,926
5	2010	20,812
6	2011	21,773
7	2012	23,495

(Source: Biro Pusat Statistik, import data for 2006-2012)

Based on the existing plant in Shell, California; by using the same process (production capacity is 35,000 tons per year), then the design capacity is 80,000 tons per year.

It is set as 80,000 tons per year because:

1. It can meet the domestic demand. It is estimated to increase from year to year as a product of the plant.
2. It opens opportunities for other industries that use TBA as a raw material to grow in Indonesia.

2. PROCESS SELECTION

There are two process to produces TBA:

a. Oxirane Process

Producing Propylene oxide from the oxidation of Isobutylene and propylene in liquid phase. This process will produce TBA as second product.

b. Process of Isobutylene Hydration

This is a production process of TBA that is added to the water on Isobutylene. Usually it called by hydration. Then the reaction is:

$$(CH_3)_2C = CH_2 + H_2O \rightarrow (CH_3)_3CHO$$

With a temperature of 70ºC and a pressure of 1.4 atm at Isobutylene conversions, then it forms TBA with 85% grade on the bubble reactor.

Then Isobutylene hydration process is selected, because:

1. TBA is main product.
2. The conversion Isobutylene become TBA is 85%.
3. Low temperature
4. No bad effect

3. THE USE OF THE PRODUCT

TBA is used for:

1. Increasing octane without pollution.
2. Dissolving denaturation of ethanol.
3. As stabilizer of Chlorohydrocarbon.
4. The raw materials of methyl methacrylate's oxidation and esterification.
5. The raw materials of ether glycol, tertiary butyl phenol.

4. PLANT LOCATION

The choice of location in Balongan, Indramayu. Based on the following considerations primary factor and secondary factor. The primary factors directly affect the main purpose of the plant which includes the production and distribution of products and arranged according to the kind and quality, time and place required by customers at an affordable price level while the plant is still obtain a reasonable profit.

5. PROCESS STEP

There are three stages to make TBA: preparation of raw materials stage, the formation of TBA stage, separation and purification.

- Preparation of Raw Material Stage
  a. Isobutylene

     Isobutylene is kept in a saturated liquid in the storage tank (F-200) at temperature of 32°C and pressure of 2 atm. The pressure will be reduce by expansion valve become 1.4 atm. Then the liquid will be evaporated partly within the Vaporizer (E-610) and the vapor that form will passing Heat Exchanger (E-110) to increase the temperature become 70°C. Then vapor will fed to the reactor (R-100).

  b. Water

     Water is taken from Cimanuk River. After processing in utility units, the water is stored in the storage tank (F-100) by a temperature of 32°C and a pressure of 1.4 atm. Then the water is pumped to the Heat Exchanger by pump (E-110). Temperature is raised by Heat Exchanger (E-110) to 70°C and a pressure of 1.4 atm. Then it is fed to the reactor (R-100).

- The Formation of Tertiary Butyl

  This stage is the stage of Isobutylene reaction with water in the reactor. Gaseous reactants Isobutylene and water fed to the reactor that operates at a pressure of 1.4 atm. The reaction is exothermic reaction, cooling is required to maintain the reaction temperature. Coolant that used is the type of coil. That is where the cooling is dipped into the liquid in the reactor. Cooling is to maintain a constant temperature of reactor, which is 70^{o}C. This is because

the reaction to the formation of TBA is isothermally. The reaction of the residual gas out through the top and returned through the pipe reactor. Isobutylene reactant, reacts to form TBA until the conversion reaches 85%.

- Purification Stage

  Purification stage is to separate a mixture of TBA and water by residual unreacted hydrocarbon, so that it produces TBA with a composition of 99.5%.

  Bottom results of Reactor (R-100) is pumped into the Heat Exchanger (E-112) to be heated, so that the temperature of 70ºC into 84.55ºC. Separation occurs in the Flash Drum (H-100) at a pressure of 1 atm. The top result of the flash drum in the form of gas fed to distillation column-01 (D-100) and bottom results pumped to the accumulator 4 (F-430).

  There is a separation in the distillation column 1 (D-100) between the TBA from a mixture of hydrocarbons that is derived from the flash drum. The products of the distillation column-01 is TBA that condensed using total Condenser (E-210). Then collected in Accumulator 1 (F-500). Part of it back to the column and the others will be pumped to Accumulator 3 (F-420).

  TBA from the distillation column-01 (D-100) is purified in distillation column 2 (D-110), and its products are condensed by the total condenser (E-211). Then collected Accumulator 2 (F-600). Part of it back to the column and the others will be pumped to Accumulator 3 (F-700). The main product are TBA with a purity of 99.5%.

  Then, byproduct from Distillation Column 2 (D-110) are TBA with the low purity, it is 67.35%. Cooling with the cooler to a temperature of 32ºC is done before it entered into the storage tank, so that product can be stored at ambient temperature. The main products are stored in the main storage tank (F-300) and byproducts are stored in the byproduct storage tank (F-400).

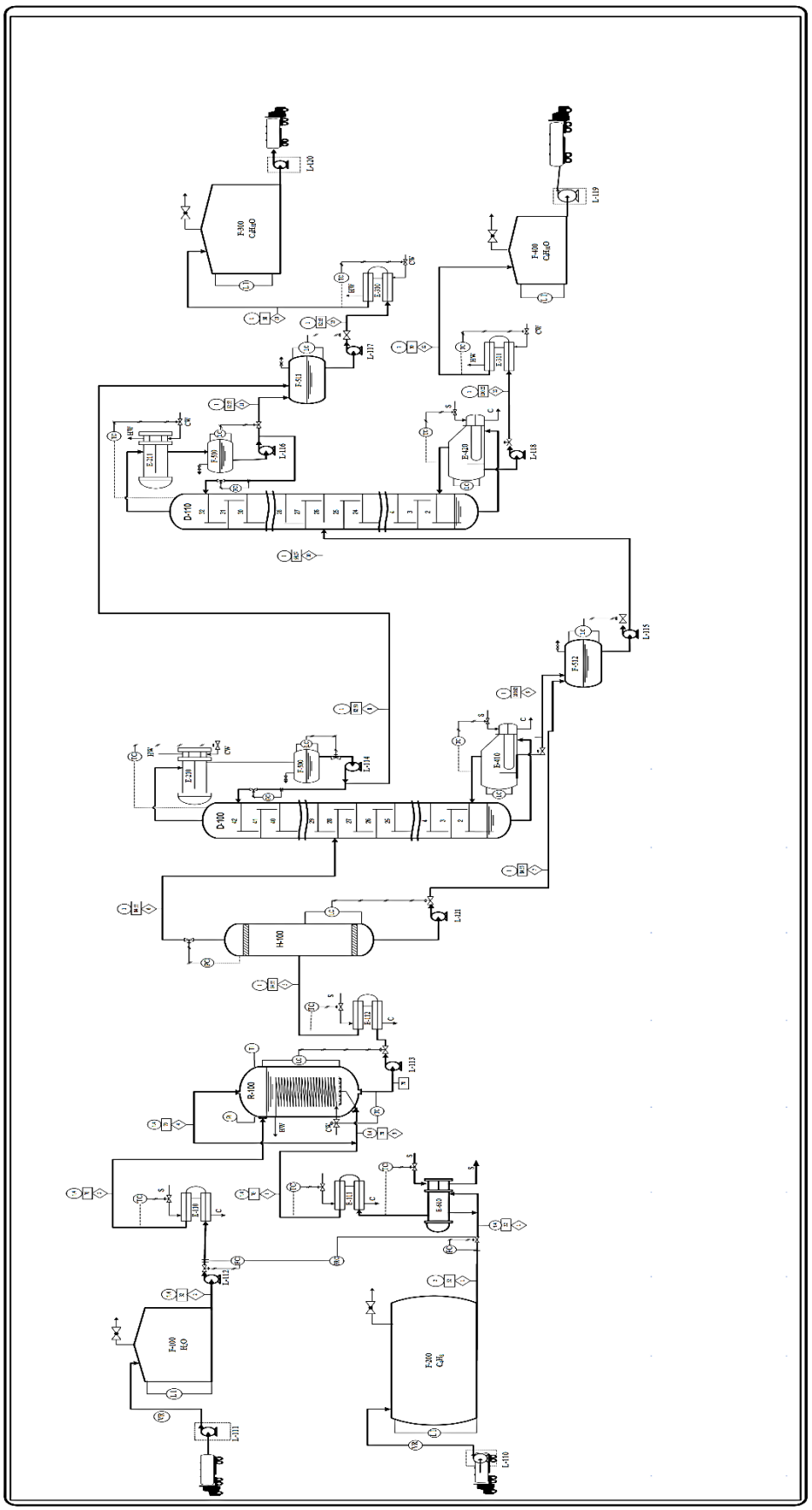


Figure 1. Flow Chart of TBA Manufacture

6. REACTION CONCEPT

a. Basis of Reaction

Making of TBA with isobutylene hydration process occurs in the reactor with operating temperature of 343.15 K and a pressure of 1.4 atm. The reaction is:

$$(CH_3)_2C=CH_2+H_2O \rightarrow (CH_3)_3CHO$$

b. Thermodynamic Review

Thermodynamics review is determine whether the reaction releases heat (exothermic) or requires heat (endothermic), and also to determine whether the reaction works reversible or irreversible.

To determine whether the reaction was reversible or irreversible, then it can be known by determining the price of K. If the value of K is large, then the reaction towards the right. Conversely, when the value of K is small, then the reaction will move back and forth. Price K can be searched by the following equation:

$\Delta G^o = -RT \ln K$;

With

K = equilibrium constant of reaction

T = Temperature

R = Gas constant, 1.987kkal/kmol. K

Where,

No	Component	ΔH_f^o (kJ/kmol)
1	$(CH_3)_2CCH_2$	-16.903
2	H_2O	-275.83
3	$(CH_3)_3COH$	-312.4

$\Delta H = \Sigma\Delta H_{f\ product} - \Sigma\Delta H_{f\ reaktan}$

= -312.400 - (-16.903 + (-275.830))

= -19.667 kJ/kmol

=-19.667kJ/kmol x 0.2389 kcal/kJ

ΔH = - 4.698,4463 kkal/kmol

Because ΔHf value is negative, then the reaction that occurs is exothermic. In the liquid phase has a price standard enthalpy change,

$\Delta H_{,298}$: - 19.667 kJ / kmol = - 4698.4463 kcal / kmol.

$\Delta G = \Sigma \Delta G_{f\ product} - \Sigma \Delta G_{f\ reactan}$

$= \Delta G_f (CH_3)_3COH - (\Delta G\ (CH_3)_2CCH_2 + \Delta G\ H_2O)$

=-191.4014 - (57.8199 - 228.6349)

= -20.5864 kJ/kmol

=-20.5864kJ/kmolx0.2389 kkal/kJ

ΔG = -4,918.1127 kkal/kmol

$\ln K_0 = \Delta G/-RT$

$= \frac{-4{,}918.1127}{-1.987 \times 298.15}$

= 8.3017

K_0 = 4,030.6234

When T operation is 70ºC = 343.15 K

$\text{Ln}\frac{K}{K^\circ} = -\frac{\Delta H}{R}.\frac{T - Tref}{T.Tref}$ (J.M. Smith, 1981)

$= -\frac{-4{,}698.4463}{1.987} \text{ x } \frac{343.15 - 298.15}{343.15 \times 298.15}$

= 1.0400

$\frac{K}{K^\circ}$ = 2.8293

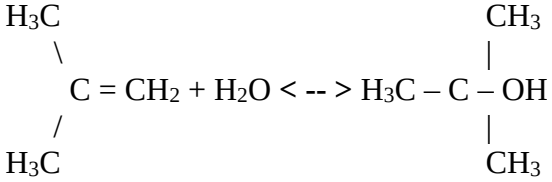
K = 4,030.6234 x 2.8293

= 11.403,9657

The big K indicates that the forming reaction of TBA is irreversible.

c. Kinetics Review

Reaction occurs:



The equation of the reaction velocity constant value at a pressure of 250 kPa is

$k = \exp\left(15.03 - \frac{8844}{T}\right)$ (Velo, et al, 1988)

With:

k = reaction velocity constant

T = Temperature, K

7. EQUIPMENT SPECIFICATION

a. Reactor

Code : R-100

Function : Reacting isobutylene (C_4H_8) and water (H_2O)

Type : Bubble Reactor

Operating Syst. : Isothermal non adiabatic

Operating conditions :

- Temperature : 70°C
- Pressure : 1.4 atm

Dimensions of reactor

- Diameter : 2.3743 m
- Volume : 23.9023 m^3
- Height of reactor : 6.3379
- Shell Thickness : 1/4 in
- Head Thickness : 1/4 in

Cooling : Coil

- Number of winding : 5.0697

Material : carbon steel

Number : 1

Price, $: US$ 552,630.1448

b. Distillation Column I

Code : D-100

Function : To separate butanol and TBA as much as 10,107.7574 kg/hour

Type : Plat Sieve Tray

Material : Carbon steel SA – 283 Grade C

Price : US$ 21,058.9105

Specification :

a. Top distillation Column

- Pressure : 1 atm
- Temperature : 355.6878 K
- Diameter : 1.6114 m

b. Bottom distillation Column

- Pressure : 1 atm
- Temperature : 373.0208 K
- Diameter : 1.0905 m

Thickness of head : 3/16 in

Thickness of shell : 3/16 in

Height of head : 15.3391 in

Height : 20.0292 m

Number of actual plate : 42

Number : 1

c. Distillation Column 2

Code : D-110

Function : To separate butyl alcohol and TBA as much as 496.6790 kg/hour

Type : Sieve Tray

Material : Carbon steel SA 283 Grade C

Price : US$ 119.026,79

Specification :

a. Top distillation Column :

Pressure : 1 atm

Temperature : 357.4016 K

Diameter : 0.6325 m

b. Bottom distillation Column:

Pressure : 1 atm

Temperature : 373.2677 K

Diameter : 0.4282 m

Thickness of head : 3/16 in

Thickness of Shell : 3/16 in

Height of head : 5.1653 in

Height : 13.6624 m

Number of Actual Plate : 29

Number : 1

8. UTILITY

Process support unit is often called the utility unit is an important part to support the life of a process in a plant. Process support units include: Provision of water (cooling water, sanitary water, boiler feed water, process water), steam, electricity, fuel, and the provision of compressed air.

In fulfill the water needs of an industry, in general, it uses well water, river water, lake water and seawater as the source for their water. In designing this the plant, water from the river Cimanuk, West Java.

a. Water Provider Unit

Water Consumption in TBA plant as much as 88,384.4799 kg/hour to fulfill the needs of cooling water is about 68,773.5725 kg/hour, steam is about 17,106.6228 kg/hour and 2,399.3050 kg/hour for sanitation.

b. Electricity Provider Unit

The consumption of electricity is about 550 KW.

c. Fuel Provider Unit

The consumption of diesel fuel is about 3.9287 m^3/hour. This amount is used for operated the generator.

d. Compressed Air Unit

The requirement of compressed air is about 50 m^3/hour. Compressed air is used for operated the instrument tools.

e. Waste treatment

Liquid waste from TBA plant are:

- Water that contains organic substances
- Domestic liquid waste (water sanitation)
- Back wash filters, oily water from the pump
- Blow down cooling water

f. Laboratory

The existence of the laboratory in a plant is very important in supporting the process of production and maintain product quality.

The functions of laboratory are:

- It is to analyze the raw materials and supporting materials of the process.
- It is to analyze and research the marketing product.
- It is to check the condition of flow process to succeed the process.
- It is to check the level of substance that cause pollution.

9. PLANT MANAGEMENT

The classification of the plant is:

Corporate form	: Limited company
Status	: Private Company
Production capacity	: 80.000 Tons/ year
Location	: Balongan, West Java
Labor	: 125 person

The considerations of the limited company are:

a. Legal entity.
b. Different from the personal assets of government assets.
c. Shareholders must be free of debt to the company.
d. The company's life more secure. This does not affect the cessation of shareholders, directors and staff and employees of the company.
e. Efficiency. The shareholders are on the board. They can choose a board of directors including qualified and experienced chief executive officer.
f. Fields broader effort. A limited company can attract huge capital from the public so that a limited company can expand its business.

10. ECONOMIC ANALYSIS

Economic analysis is very important in built up the plant. It is caused by economic analysis can be used for classified that plant is feasibility to build. From economic analysis that had been done, can be obtained that TBA plant is feasible to established.

a. Profit before tax is 271,474,519,769.99 IDR per year.
   Profit after tax 190,032,163,838.99 IDR per year
b. ROI (Return On Investment) before tax 56.52%
   ROI after tax 39.52%
   ROI before tax. The minimum low risk of the plant is at 11%.
c. POT (Pay Out Time) before tax 1.5 years
   POT after tax 2 years
   POT before tax. The maximum low risk of the plant is at 5 years.
d. BEP (Break Even Point) is at 42.92% and SDP (Shut Down Point) is at 28.46%. BEP for common chemical plant is around 40% - 60%
e. IRR (Internal Rate Return) is at 33%.

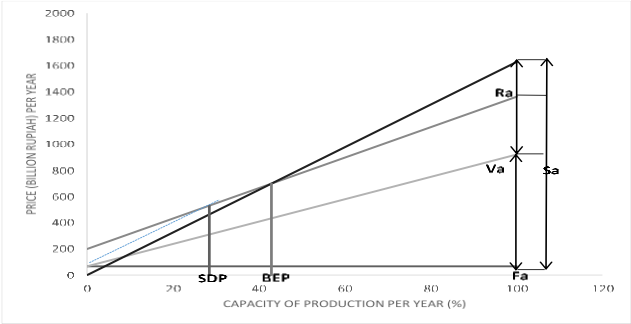


Figure 1. Economic Analysis

11. CONCLUSION

TBA plant with Isobutylene hydration process has a production capacity of 80,000 tons/year. This plant will be operated for 330 days/year with 125 employees. Based on the operating conditions, the plant is classified as low-risk plant. This is because the plant operates at low pressures. While based on the economic evaluation, the plant is classed as low-risk plant.

So that, this TBA plant is feasible to be built.

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